Allograft replacement of distal radius for giant cell tumor

Three cases of resection of the distal radius with allograft replacement for giant cell tumor of bone were reviewed. In one patient the tumor had penetrated the distal articular cortex; in another it had broken through the anterior cortex; in the third there had been recurrence of the tumor within a year of curvature and autogenous bone graft. In each case the allograft was glycerinated to help to preserve the viability of the articular cartilage and then it was frozen at $-70^\circ$ C to decrease bone antigenicity. In all three patients rapid healing at the recipient-graft juncture took place, and none showed signs of rejection or of recurrence of the tumor. All three have a useful and relatively painless range of wrist motion. Distal radial resection and allograft replacement is recommended for giant cell tumor of bone if there has been spontaneous cortical or articular breakthrough, recurrence, or evidence of a rapidly enlarging lesion or a frankly malignant histologic appearance.

Richard J. Smith, M.D., and Henry J. Mankin, M.D.,
Boston, Mass.

Giant cell tumor of bone is an aggressive lesion, which has a high rate of recurrence. The lesion may become malignant and metastasize to the lungs and elsewhere. The problem of selecting the proper treatment for giant cell tumor of bone is complicated by the failure of its histologic appearance to indicate its biological behavior. The histologic grading of the tumor on the basis of the degree of stromal cell atypism is of little prognostic significance. The overall recurrence rate, with or without radiation, is reported in 42% of 53 cases, 44.6% of 195 cases, and 62% of 76 cases. A total of 2.3% to 6.2% of giant cell tumors of bone are frankly malignant.

Various methods of treatment have been suggested for giant cell tumor of bone, including curettage, bone graft, local excision, cautery, cryosurgery, resection, amputation, radiation, and combinations of these procedures. Local recurrence of the tumor after operation or radiation is most difficult to treat. Only en bloc resection or amputation has consistently resulted in cure of giant cell tumor of bone.

Although giant cell tumor most frequently affects the distal femur and proximal tibia, involvement of the distal radius is not rare. Twenty of the 195 cases (10%) of primary giant-cell tumor reported by Dahlin, Cupps, and Johnson were in the distal radius, as were nine of the 48 cases reported by Hutter et al. and five of the 53 cases reported by Larsson, Lorenzon, and Boquist. Of the nine cases reported by Hutter et al., six recurred after primary treatment; of the five cases reported by Larsson et al., three recurred after primary treatment.

In view of this high rate of recurrence of giant-cell tumors of bone, including those of the distal radius, en bloc resection, where feasible, appears to be the treatment of choice for any lesion which has recurred at least once, has broken through the cortex, has enlarged rapidly or is frankly malignant on histologic examination. Although amputation of the forearm and hand would be curative, it would seem unwarranted for a lesion which rarely metastasizes.

Following distal radial resection, many methods have been proposed to achieve wrist stability. Iliac and tibial bone grafts will result, at best, in a fused wrist and will require prolonged immobilization while revascularization of the graft occurs. Fibular bone grafts may provide motion and stability to the wrist, but, due to incongruity of the joint surfaces, severe osteoarthritic changes at the articular surface of the fibula often
result in a painful and relatively immobile wrist.\textsuperscript{11} Large metal and acrylic prostheses have been used with poor results.\textsuperscript{12} If the resected bony segment could be replaced by a distal radial allograft of similar size and shape, both stability and mobility of the wrist should be preserved.\textsuperscript{13}

There are many potential problems, however, with allograft replacement. Selection of a suitable donor, the methods of obtaining and preserving the graft, and the technique of tumor excision and allograft replacement deserve particular attention. After operation the surgeon must consider the risks of infection, or graft rejection, delay of healing of the graft-recipient bone juncture, the time required for allograft replacement by the host bone, and the ultimate stability and mobility of the wrist joint.\textsuperscript{14-18}

The purpose of this report is to document our experience with three patients with giant cell tumor of the distal radius who were treated by local resection and allograft replacement.

**Technique of allograft replacement**

On the basis of previously documented clinical and experimental studies, as well as the personal experience of one of us (H.J.M.) with 28 allografts used in the treatment of aggressive or malignant bone tumors, a protocol for allograft replacement has been formulated.\textsuperscript{14-21}

The donor bone is obtained within 12 hours of the donor’s death, under sterile operating room conditions. The donor must have been between 15 and 45 years of age, free of infection or neoplasm, and must not have received high doses of corticosteroids for longer than 5 days prior to death. All soft tissues other than ligament and tendon attachments are removed from the donor bone, and cultures are taken of the bone surface, marrow cavity, cartilage, and donor heart blood. Cartilaginous surfaces of the excised bone then are immersed in dilute glycerol solution for 15 minutes and the graft then is wrapped in sterile towels, x-rayed, and refrigerated at 4° C for 18 hours in order to allow the glycerol to penetrate the cartilage cells. Glycerinization of cartilage during freezing prevents ice crystal formation and thus, theoretically at least, helps to maintain the viability of the chondrocytes. The survival of donor chondrocytes will help to decrease the immunologic response and subsequent destruction of the cartilage, since viable articular cartilage will maintain a matrix with a pore
Fig. 1C. Case 1. Through a dorsoradial incision, the distal 6.5 cm of the radius was excised.

Fig. 1D. Case 1. A distal radial allograft, obtained some weeks previously, had been removed with the attachments of the wrist capsule. It had been cultured, the cartilage glycerinized, and the specimen frozen at \(-70^\circ\text{C}\). It was allowed to thaw in the operating room and is compared in this photograph to the excised surgical specimen.

size so small (68 Å) that antigens cannot "leak out" nor can antibodies gain access to the cartilage cells.\(^{14}\) After 18 hours of refrigeration at 4° C, the bone is stored at \(-70^\circ\text{C}\) until needed. Several authors have found that the immunogenicity of allograft bone is decreased when it is preserved at these low temperatures, although the issue still remains in doubt.\(^{21}\)

Prior to operation the patient receives a thorough clinical, laboratory, and radiographic study, including bone scan and chest tomography, to rule out metastatic lesions and to clearly delineate the extent of the bone tumor. An allograft is selected of the proper size and shape and from the same side as the bone tumor.

The allograft is permitted to thaw during the operative procedure. Tumor bone is removed en bloc with periosteum and soft tissue in the region of recent biopsy or cortical breakthrough. The allograft is cut to size, inserted in the defect, and held with appropriate internal
brachioradialis was detached and the pronator quadratus was excised with the tumor bone. The allograft replacement was fixed to the patient’s proximal radius with a compression plate and the wrist joint was supported for 3 to 4 weeks with a longitudinal Kirschner wire. Ligaments removed with the allograft were sutured to the recipient ligaments which remained on the carpal bones. The limb was immobilized in a plaster cast for 6 to 8 weeks and supported in a volar splint for 1 or 2 months thereafter.

Case histories

Case 1. A 22-year-old right-handed carpenter fell, injuring his right wrist. He had had a history of vague stiffness about the wrist for 6 months previously. Roentgenograms showed an eccentric 2.2 cm diameter lytic lesion at the distal end of the radius. There was a pathologic fracture at the distal end of the radius in the region of the tumor and a suspected subchondral fracture at the wrist. A biopsy was performed elsewhere, revealing “typical” giant cell tumor of bone.

Two and one half weeks after the injury, he was admitted to the Massachusetts General Hospital where a metastatic bone series, chest tomography, and Tc-99M bone scan were negative, save for the region of the distal radius.

Through an elliptical incision, the biopsy scar and soft tissue down to the dorsum of the radius were excised. The extensor tendons were retracted radially, and the radius was divided 6.5 cm proximal to its distal articular surface. The brachioradialis was detached and the radiocarpal and radioulnar ligaments were transected just proximal to their distal attachments. The pronator quadratus was excised with the radius.

The donor bone was cut to the size of the resected radius and held to the proximal radius with a six-hole compression plate. A longitudinal Kirschner wire was placed between the third and fourth metacarpals, through the contiguous carpal bones, and into the distal end of the allograft. The ligaments attached to the allograft were sutured to the distal end of the patient’s transected radiocarpal and radioulnar ligaments with interrupted nylon sutures. The wound was closed, and a long arm plaster cast was applied with the wrist and forearm in neutral position.

Laboratory examination of the resected bone demonstrated cortical defects at the dorsal ulnar side of the radius and in the subchondral bone extending through the cartilage and into the wrist joint. There was a “biopsy bulge” 1.3 cm in diameter. Microscopic examination revealed the bone to have been excised 2.5 cm from the tumor margin. Tumor cells were found to have invaded the peristeme and the adjacent soft tissue but were confined by muscles laterally and ventrally.

The Kirschner wire was removed 3 weeks after operation. The plaster dressing was removed 2 months after operation. He continued to use a volar splint intermittently for 6 months.

At no time were there any postoperative constitutional fixation. Ligaments are resutured. After operation the patient is placed on antibiotics but not on steroids or immunosuppressives.

Radial allografts

Three patients with giant cell tumors of the distal radius were treated with en bloc excision of the distal radius and allograft replacement. In each the protocol outlined above was used. The patient’s distal radius and the adjacent soft tissues were removed about 3 cm proximal to the radiographic margin of the tumor. In one patient (case 2), the distal ulna also was removed due to distal radioulnar incongruity. The tendon of the
symptoms, local redness, heat, or swelling. Edema of the hand was minimal. The recipient-graft bone juncture healed without incident 3 months following operation.

The patient has been followed 33 months subsequent to operation, during which time he has returned to work as a postal employee. Most recently, examination showed wrist dorsiflexion of 20°, palmar flexion of 45°, radial deviation of 20°, ulnar deviation of 0°, forearm supination of 90°, and pronation of 60°. The grip of his right hand was 55 pounds, and the left hand 110 pounds.

Roentgenograms taken 31 months after operation showed no evidence of recurrent tumor. There has been mild fragmentation of the volar lip of the distal radial allograft. Volar subluxation of the carpus first was noted 1½ years following operation. The patient has no complaints of pain, however, and uses the extremity without difficulty for most tasks (Fig. 1).

Case 2. A 24-year-old ambidextrous law student noted pain and weakness in his right wrist while playing tennis 5½ months prior to admission to the hospital. The pain gradually resolved, but 3 months later he fell while hiking and he noticed increasing pain and swelling about the wrist. Roentgenograms showed an eccentric radiolucent lesion 2.3 cm in diameter at the distal radius (Fig. 2). Clinical, radiographic, scanning, and laboratory examination showed no evidence of abnormality other than of the distal radius.

He was admitted to the hospital for biopsy and definitive treatment. At the time of curettage of the lesion, a defect was noted in the anterior cortex of the radius. Microscopic examination of the excised lesion revealed giant cell tumor. In view of the cortical breakthrough, the wound was closed to await a suitable donor allograft.

Two months after biopsy, the distal radius was removed and a 5.5 cm distal radial allograft was inserted in the defect and held with a dorsal compression plate. The distal ulna was excised because of incongruity at the distal radioulnar joint. A Kirschner wire was inserted through the carpus and allograft in order to stabilize the wrist. It was removed after 2 months (Fig. 3, A). Microscopic examination of the specimen revealed tumor less than 1 cm from the articular cartilage. In some areas the tumor extended to not through the periosteum and approached close to the articular cartilage. The patient had an uneventful postoperative course, and all immobilization was removed after 3 months, at which time x-ray showed good union at the graft-recipient juncture.

The patient did well following operation, with only occasional aching pain in his wrist with heavy activities. Within 11 months of operation, he was playing tennis, bicycling, lifting heavy boxes, and using his hand for drilling. Thirteen months after the allograft, the compression plate was removed and trephine biopsies revealed early osteoblast activity and lamellar bone at the more proximal areas of the allograft with fragments of dead lamella cortical bone and periosteum with focal invasion by vascular systems more distally.

Twenty-three months after the allograft, wrist dorsiflexion was 30°, palmar flexion was 35°, radial deviation was 10°, ulnar deviation was 20°, forearm pronation was 70°, and supination was 80°. The grip of the right hand was 37 pounds (that of the left 130 pounds).

Roentgenograms showed solid healing in the region of the allograft-donor juncture. There was no evidence of recurrent tumor (Fig. 3, B).

Case 3. A 16-year-old right-handed female student with juvenile diabetes had noted mild pain about her left wrist for about 1 year. One month after the onset of pain she fell, and roentgenograms showed an eccentric lesion at the distal end of the radius. She was treated elsewhere by curettage and packing with autogenous iliac bone (Fig. 4).
Fig. 1G. Case 1. Sections of the surgical specimen show tumor to have penetrated through the distal articular cortex and articular cartilage and to lie within the joint space. (Hematoxylin and eosin.)

Fig. 1H. Case 1. The allograft is stabilized to the radius with a six-hole compression plate. The wrist is stabilized for 3 weeks with a longitudinal Kirschner wire.
Eleven months later, roentgenograms were repeated because of gradually increasing pain and showed recurrent tumor at the distal left radius (Fig. 5, A).

She was admitted to the Massachusetts General Hospital, and appropriate clinical and laboratory studies showed no evidence of abnormality, except about the left wrist. The distal 7 cm of radius was excised and replaced with a suitable allograft. Microscopic examination of the lesion revealed giant cell tumor with occasional mitosis per high power field. The tumor measured 2 by 4 cm. The cortex was found thinned to 2 mm at many points.

The allograft was held to the recipient radius with a six-hole compression plate, and the wrist was immobilized with a longitudinal Kirschner wire. A short arm plaster cast was applied.

One month later the Kirschner wire was removed and she was given a cock-up splint.

Six months following allograft replacement, there was virtually complete healing at the allograft-host juncture (Fig. 5, B). There was no apparent abnormality about the joint. Wrist dorsiflexion was 55°, palmar flexion was 0°, radial deviation was 20°, ulnar deviation was 15°, forearm pronation was 80°,
and supination was 45°. The grip of the left hand was 25 pounds and the right 55 pounds. She notes only “occasional throbbing” but no pain about the hand or wrist. She has resumed all normal activities except for athletics.

Discussion

The graft-recipient bone juncture healed in all three patients rapidly and without complication. In no instance was this accompanied by local heat or redness. The site of bone juncture was crossed by osseous trabecular patterns, much as one would anticipate with the healing of a fracture. Excellent intramedullary and periosteal blood supply of the recipient radius in addition to the firm apposition of the recipient and graft bone by means of a compression plate may account for this rapid healing. In addition, using a distal radial allograft provides maximum bone-to-bone contact, as the shape of the contiguous bone ends is similar. The absence of bone resorption or the clinical inflammatory signs which may accompany a rejection phenomenon attest to the low immunogenicity of the allograft bone treated with deep freezing and with cartilage glycerinization.

Volar subluxation of the wrist occurred in one pa-
tient 1 to 2 years after allograft replacement. The subluxation may reflect a loss of the tensile strength of the sutured ligaments of the allograft. With loss of dorsal ligament support, the greater power of the digital and wrist flexors as compared with those of the digital and wrist extensors could cause the gradual volar subluxation and erosion of the volar lip of the distal radius. This mechanism may be similar to the gradual volar subluxation of the carpus with erosion of the volar lip of the distal radius which occurs with chronic rheumatoid arthritis after dorsal ligament or tendon support about the wrist has been lost. In the future we plan to support the dorsum of the wrist with appropriate tendon transfers to avoid this late complication. In the patients already treated, if the volar subluxation increases or becomes symptomatic, wrist arthroplasty or arthrodesis may be necessary.

Conclusions

Giant cell tumor of bone must be considered an aggressive, potentially malignant lesion with a high incidence of recurrence after curettage and/or radiation. In some cases, giant cell tumor of the distal radius may
Fig. 4. Case 3. A. Anteroposterior view of the wrist taken 1 month after initial bone grafting. B. Two months after bone grafting, a small area of radiolucency can be seen at the radial styloid and to the ulnar side of the distal end of the radius.

Fig. 5. Case 3. A. Nine months after bone grafting this xerogram reveals the radiolucent areas at the distal radius continue to enlarge. B. The distal 7 cm of the radius was excised and replaced with an allograft. Roentgenograms four months after allograft replacement of the distal radius show mild ulnar subluxation of the carpus. She has excellent motion of the wrist and notes only “occasional throbbing.”
be cured by resection of the tumor bone and the adjacent soft tissues. Replacement of the resected distal radius with an allograft may prove an effective means of reconstructing the wrist joint. It would appear that if proper precautions are taken regarding the treatment of the allograft and its insertion, useful though incomplete wrist motion may be anticipated. One of our patients developed volar subluxation of the wrist between 1 and 2 years subsequent to the insertion of the allograft. Additional procedures may be required in the future to stabilize the wrist if subluxation becomes more severe. If giant cell tumor of the distal radius has had a rapid onset, has broken through the cortex spontaneously, has recurred, or is frankly malignant, histologically, distal radial resection and its replacement with an allograft may be indicated. Amputation should be considered if there is extensive soft tissue involvement after pathologic fracture of the radius at the site of malignant giant cell tumor.

REFERENCES

Invited editorial comment

Crawford J. Campbell, M.D., Boston, Mass.

The biologic behavior of giant cell tumor must be understood clearly when considering its treatment. Although the possibility of metastasis is low (5%), the high incidence of local recurrence following its incomplete removal approaches 50%.

Less than 10% of giant cell tumors are found in the distal end of the radius. In this site, resection and reconstruction are certainly the procedures of choice, as they avoid serious functional loss or mutilation and minimize the chances of recurrence. The method by
which the resected distal end of the radius can best be reconstructed is in some measure dependent upon the interests and expertise of the surgeon. Each has its advantages and disadvantages, but the success of each method must be considered to be preliminary until the patients are reviewed at least 5 years after operation.

In the past, the autografts have caused fewer complications than have allografts but this picture may now be changed by better methods of allograft preservation and preparation. There are many methods of using autografts which have given very good results. One of these is the use of the proximal end of the fibula as a graft. It fits surprisingly well and often preserves good functional use of the wrist and hand. Nevertheless, the mechanical misfitting of the proximal end of the fibula with the carpal bones can be expected to cause some degenerative changes. Another method of preserving reasonable joint function replaces the distal radius with a tibial graft which is arthrodesed to the scaphoid and lunate bones. After operation there frequently is an increase in intercarpal motion resulting in useful motion.

Since the distal end of the radius is not a weight-bearing joint, it may be expected to be one of the most favorable sites for allograft replacement. With repair of the strong wrist ligaments, congruous joint surfaces and a relatively short bone length requiring replacement, radial allografts would be expected to give good short-term results. The possibility of late joint degeneration, however, must be considered.

In all cases in which giant cell tumor has occurred and bone grafts have been inserted, careful periodic evaluation must be performed to determine if there has been recurrence or metastasis and to note the status of the graft. In time, the advantages and disadvantages of various techniques in managing giant cell tumor should become more evident.